

## ON AMPUTATION OF THE THIGH.

By JOHN GREEN, FELLOW OF THE MASSACHUSETTS MEDICAL SOCIETY, LATE ACTING ASSISTANT SURGEON U.S.A.

[Communicated for the Boston Medical and Surgical Journal, June, 1863.]

It has been my duty during the past year to direct the treatment of a large number of soldiers who had suffered primary or secondary amputation of large limbs. Some of these cases were received immediately after the performance of the operation; the others after intervals varying from two or three days to as many weeks. An opportunity was thus afforded to observe the effects, in some instances, of neglect, and in others of good treatment, and to compare the results of various operative methods as practised by different surgeons. The study of these cases, followed by a partial review of the history of amputations, has led me to some conclusions which may perhaps be of interest to others.

I propose, therefore, to study some of the general questions connected with the subject of amputation of the thigh, adopting the usual division into circular and flap methods.

## CIRCULAR AMPUTATION OF THE THIGH.

Before discussing any of the ordinary methods of operating, it may be profitable to study the very simple case of a circular amputation of the thigh in which all the soft parts are divided by a single sweep of the knife, and the bone sawn at the same level. After such an operation, the end of the stump at once assumes a conical form, from the retraction of the muscles; the muscular fibres which lie nearest to the bone, and which arise from or are inserted into it near its sawn extremity, contract but little, while the longer fibres and muscles, which are farthest removed from the axis of the limb, contract most, drawing with them the cut margin of the skin. This muscular cone soon becomes covered with granulations, which also arise at a later period from the cut end of the bone. As the process of cicatrization advances, the edges of the skin are gradually drawn towards the centre of the stump, and the superficial cells of

the granulating bone become developed into an imperfect cuticle, which remains always tender, and from its exposed situation is subject to continual abrasions. Often the extremity of the bone exfoliates, after a tedious suppuration, a result much desired by the older surgeons, who were always careful to promote necrosis by the use of the hot iron and of caustics. The legitimate result, then, of such an operation is the miserable failure known as a "conical stump"; granulations form upon the soft parts and begin to retract before they have appeared at all upon the compact tissue of the bone, and the contraction of the cicatrix tends quite as much to draw the flesh away from the bone as to draw the skin towards it.

#### OLD OR "COMMON" CIRCULAR AMPUTATION OF THE THIGH.

The defects of this primitive kind of amputation were early recognized, and attempts were made to preserve enough of the soft parts to cover the end of the bone. This covering may be either of skin, or muscle, or both.

The origin of the practice of saving skin as a covering to the stump, is attributed to Cheselden and to J. L. Petit. These surgeons made first a circular incision of the skin and subcutaneous tissue, which was then drawn upwards by an assistant, or turned over like the cuff of a sleeve. A single sweep of the knife, applied close to the margin of the retracted skin, divided the remaining soft parts, which were drawn upwards by means of a "retractor," and the bone was sawn, as nearly as possible, at the level of the section of the muscles. This was a great improvement, and was at once adopted by English and French surgeons, but it by no means fulfils all the conditions of a good amputation, as I can testify from the study of several cases which I have had to treat. These stumps, a few days after the operation, generally presented a conical mass of retracted and granulating muscle, from the apex of which projected the end of the bone, not yet covered with granulations, and often denuded and dead for perhaps half an inch from its extremity. Surrounding the base of this cone of retracted muscle was the cuff of skin, barely sufficient, when brought together, to cover the end of the muscular mass, leaving the bone either wholly exposed between its lips, or else pressing so hard against the thin covering as to cause much pain, and even sometimes to make its way through by inducing rapid ulceration or sloughing. Even if the lips of the wound had already united by first intention,\* the pressure of the still sharp end of the bone against the skin or new cicatrix threatened to open it again. At the best, the result was very imperfect, for

\* I use this term in the sense in which it is employed by modern writers on surgery, including under it the two processes described by Hunter as "union by first intention" and "union by adhesion or adhesive inflammation," and which are more accurately designated by Mr. Paget by the names "immediate union" and "primary adhesion." In the healing of large wounds it is not easy, practically, to discriminate between these two modes of repair, and it is therefore convenient to retain this expression for the union which takes place prior to and independent of the formation of granulations.

the bone always remained very prominent, even if it became covered by skin, which was seldom the case.

The idea of protecting the end of the bone by preserving a cushion of muscle is as old as the time of Celsus,\* who directs that the bone be separated from its attachments, for some distance above the level of the section of the muscles, and sawn as high as possible. Let us now study the effect of this shortening of the bone upon the progress and nature of the cure. The muscular section assumes, as in the last case, a conical form, owing to the greater retraction of the more superficial muscles, but the end of the bone, instead of forming the apex of the cone, lies buried among the muscles at the bottom of a deep pit or crater. As cicatrization advances, the edges of this crater are gradually drawn outwards towards the skin, whose margins are at the same time being drawn inwards towards the bone. The consequence is, that the crater becomes shallower, but the bone, if it has been cut short enough, and has not been separated from its attachments above the point where it was sawn, will still lie, safe from external injury, at the bottom of a little cavity in the end of the stump.

This precept of Celsus seems to have been forgotten until about the middle of the eighteenth century, when it was revived by Mr. Gooch,† an eminent surgeon of Shottesham, in Norfolk, in England. Gooch commenced his operation by dividing the soft parts, in the manner of Cheselden and Petit, by a double circular incision, but his great improvement consisted in the separation from the bone of the deep muscles and fasciæ to the additional height of about two inches, and sawing the bone at this higher level. Precisely the same operation was described several years later, by Mr. Benj. Bell,‡ who was perhaps the first to distinctly inculcate the principle of "saving as much of the muscular substance of the limb as will completely cover the bone, together with as much skin as will cover the whole surface of the stump."§ Bell states that by this method "the stump is covered with sound skin, as well as with some muscular substance, which admits of the patient resting upon it with freedom";|| and Gooch, in the description of a case, says that "the cicatrix was but a few lines broader than the diameter of the bone, which was left concealed in a little cavity."¶ In the operation of Gooch and B. Bell, the separation of the muscles from the bone was effected by plunging a sharp-pointed knife or scalpel perpendicularly into the face of the stump, by the side of the femur, and carrying it, in the same position, entirely around the bone. In executing this manœuvre there

\* Celsus. *De Medicina*. Lib. vii., cap. xxxiii., *De Gangrena*.

† Cases and Practical Remarks in Surgery, &c. By Benjamin Gooch, Surgeon. London, 1758. Page 124.

‡ *A System of Surgery*. By Benjamin Bell. Edinburgh, 1783. Vol. vi., p. 301 et seq. on Amputations.

§ *Ibid*, vol. vi., p. 357.

|| *Ibid*, vol. vi., p. 378.

¶ *Cases in Surgery*, p. 126.

is danger of separating the bone unequally from its attachments, and it may easily happen that the bone will be denuded, upon one side or the other, higher than the point where it is to be sawn. From this cause partial exfoliation of the bone may occur, with the effect both of retarding the cure and impairing the final result.\* A better way of effecting the same object is to apply the retractor immediately upon the completion of the circular section of the muscles, and then to divide, in succession, with the edge of the amputating knife, such bridles of tendon or fascia as oppose themselves to the retraction. The chief obstacles to the retraction of the muscles will be found at the back part of the femur, in the aponeurotic tissues which are inserted into the *linea aspera*; and by dividing these in the manner described, the bone may be denuded to any desirable extent. After a sufficient portion of the bone has been thus exposed, it is well to make a final circular sweep of the knife close to the retractor, so as to divide the periosteum and thus guard against its possible laceration by the teeth of the saw.†

This improved circular amputation, excellent as it is, has still an important defect. The muscles, which are divided in a plane perpendicular to the axis of the limb, immediately retract, and the section, from causes already explained, assumes the form of a cone. It would evidently be better if the cut surface of the muscles were made flat, instead of conical, for the bone would be better protected, and less skin would be required for a covering. This idea was in fact put in execution by the great French surgeon Ambrose Paré,‡ who anticipated the retraction of the muscles by drawing them firmly upwards and holding them there while he made a single circular incision of all the soft parts. The same advice is also given by the distinguished Scotch anatomist and surgeon, Alexander Monroe,§ who expressly states that his object is to secure a perfectly flat section of all the tissues of the limb. This flatness of the muscular tissue is most easily, and, at the same time, most surely attained by dividing the deeper layers of muscle twice. After the first section of the muscles, the soft parts are drawn upwards by an assistant,|| and the deeper fibres again divided down to the bone. The retractor is

\* Gooch guarded against this danger by using, in this part of the operation, a knife bent so that the angle of the blade served as a guide to regulate the depth to which it could enter.

† The retractor invented by Gooch and adopted by B. Bell was made of strong leather, which has the great advantage over linen or cotton, that it does not impede the action of the saw by catching its teeth. This is a matter of some importance, for I have seen a surgeon cut the bone half an inch too low, rather than run the risk of getting the teeth of the saw caught in the threads of the retractor. Others have been led, for the same reason, to discard the retractor altogether, at the risk both of leaving the bone too long, and of tearing the flesh by the saw—which, to say the least, produces an unfavorable impression on the minds of the bystanders.

‡ Works of Ambrose Paré. Book xii., chap. xix., on Amputation.

§ Medical Essays and Observations, &c. Edinburgh, 1735. Vol. iv., Art. xxii.

|| The aid of an assistant in this part of the operation is indispensable in amputations performed under the influence of anæsthetic agents. Most of the standard writers on surgery speak of the spontaneous retraction of the muscles at the instant of their division by the knife, but this spontaneous muscular retraction does not occur when the reflex nervous action is suspended by a full dose of ether or chloroform.



then applied, the tendinous attachments at the linea aspera are divided, and the bone is sawn as high as may be thought proper.

This completes the history of one form of the circular amputation in the thigh. The essential points to be observed in its performance are—1st, To preserve skin enough to cover completely the end of the stump, without stretching. This rule is imperative if we hope for a cure by first intention,\* but it need not be so strictly observed in cases where the wound is to be left to heal, from the first, by granulation. 2d, To divide the muscles so as to make the section as flat as possible. This is best effected by dividing the muscles down to the bone by two successive sweeps of the knife, beginning the second cut at the base of the cone formed by the retraction of the outer and longer muscular bundles. 3d, To separate the femur from its attachments at the linea aspera, and to saw the bone so high that it may be completely hidden in the muscles after the removal of the retractor.

In the normal condition of the tissues of the thigh, this operation may be easily and expeditiously performed; the divided integuments are easily retracted to the requisite extent by simply cutting the few bridges of loose connective tissue which tie it down to the fascia, and the muscles are as easily separated from the bone by dividing their attachments at the linea aspera. This operation is, therefore, well adapted to cases of primary amputation for injury, and to such chronic cases as have not been attended with inflammation of the parts in which the incisions are to be made. If, on the other hand, we have to deal with a case in which the limb has become inflamed, we shall find the various tissues so firmly glued together that it will require a laborious dissection to separate them. The skin will no longer slide upon the fascia, but will have to be carefully dissected from it and turned back like a sleeve; the muscles, too, cannot be retracted, at the time of the operation, without much difficulty, but will make up for this by excessive shrinkage at a later period. There is danger, therefore, that the bone may not

\* The skin saved for this purpose need not be in the form of a cuff; in fact, this form is not that best adapted to the formation of a symmetrical stump, for there will always be prominent "ears" of skin at the angles of the wound, which never wholly disappear. The more perfect (i. e. the flatter) the form of the muscular section, the worse does the cuff fit, and the more prominent are the "ears" of skin. It has been proposed to remove the projecting angles at the time of the operation, or what amounts to nearly the same thing, to modify the first incision of the skin by cutting it in the form of semi-elliptical flaps. Sir Charles Bell cut the skin in this form with the edge of the amputating knife, by changing its direction in different parts of the circumference of the limb (see Illustrations of the Great Operations of Surgery, folio, London, 1821). Sédillot (*Traité de Médecine Opératoire*, &c., 2me Ed., Paris, 1853, tome i., page 451) made two very thin flaps by transfixing the limb, and completed the section of the soft parts by a circular incision. The most perfect adaptation of the skin to the subjacent cut surfaces may be obtained by fashioning it in the form of either one or two flaps of a breadth equal to or a little greater than the diameter of the limb. If a single flap be chosen, its free extremity must be rounded, and its length should be slightly greater than the diameter of the limb. If, on the other hand, two flaps be made, they must be cut of a rectangular form, and may be either of equal or unequal dimensions, taking care, however, that their united lengths shall somewhat exceed the diameter of the limb. The choice between these different plans must often be decided by the state of the integuments on different sides of the limb, and will therefore depend, in a great degree, upon the nature of the lesion for which the amputation is performed.

be sufficiently protected by the soft parts, and a bad stump may be the consequence. This operation, therefore, answers better for primary than for secondary amputations, and I think it can be shown that for the latter class of cases, another method (the double-flap operation of Vermeil) is to be preferred.

The results of this operation, when performed upon a proper class of subjects and with a due regard to the three points above enumerated, are such as leave little to be desired, whether the cure be effected by first intention or by granulation. The end of the stump will be flat, or perhaps slightly rounded, with a central depression corresponding to the end of the bone, and will in most instances be capable of sustaining considerable pressure. The whole stump tapers symmetrically, and is admirably fitted to support the weight of the body in the conical socket of a modern artificial limb. If this method is adopted in cases in which the tissues have become consolidated and adherent to each other from the effect of previous inflammation, it will be easier to dissect up the skin in the form of flaps than of a cuff, and especial care must be taken to retract the muscles strongly, and to saw the bone at the highest possible point above the level of the section of the soft parts.

CIRCULAR AMPUTATION OF THE THIGH, IN WHICH THE INCISIONS ARE  
SO MANAGED AS TO GIVE TO THE SECTION THE  
FORM OF A HOLLOW CONE.

Larrey and Dupuytren adopted, in the amputation of the thigh and arm, a method by circular incisions which is, nevertheless, so different from the common operation as to demand a special description. Its chief peculiarity consists in the form of the section, which is that of a deep hollow cone,\* of which the cut margin of the skin forms the base, and the end of the bone the apex. This form is the result of several consecutive circular incisions, and is most readily obtained by the method of Dupuytren. An assistant draws up the skin and flesh as much as possible, and the surgeon, by a single circular sweep of the knife, divides all the soft parts nearly or quite to the bone. The cut surface of the muscles at once assumes the form of a cone, at the base of which the knife is again applied, and again carried round the limb, dividing everything to the bone. A third, and, if necessary, a fourth or fifth, circular section of the deepest muscular layers may be made with the greatest rapidity, and the bone is sawn in the track of the last incision. In this way the bone may be sawn as high even as six inches above the first in.

\* Several older surgeons use this expression as applicable to their own operations, but it does not appear that they really attained, or indeed aimed at, anything more than a flat, or at most a slightly concave section of the muscles. Mr. Hey, whose description of his method is nearly identical with that of Larrey, says, in fact, that "the most perfect union of the soft parts would be produced by making an incision through them all in a conical form; but [that] such an incision is impracticable in the ordinary mode of operating, nor is it necessary for the formation of a good stump."—(See *Practical Observations in Surgery, &c.*, by William Hey. 2d Ed., London, 1810, p. 529.)

cision of the soft parts,\* and the extremity of the stump presents the form of a deep conical cavity with the bone at its apex. Larrey† operated in the same manner, with the single exception that in the first incision he divided only the skin and subcutaneous tissue which were retracted by an assistant, during the performance of the rest of the operation. Desault‡ made several circular incisions, dividing the soft parts layer by layer, instead of dividing all by one sweep of the knife.

In this amputation, which as simplified by Dupuytren is extremely rapid and brilliant, the nature of the cure will depend almost wholly upon the height above the first incision at which the bone is sawn. If the conical cavity be made too shallow, or if it become so from subsequent shrinking of the soft parts, the operation will approach in character the very imperfect one of Paré; but if, on the other hand, it be of sufficient depth to admit of the coaptation not only of the skin but also of the muscular sides of the cavity, extensive union may take place by first intention or by the adhesion of the granulating surfaces, and the end of the stump will be well rounded, with the bone deeply buried at its centre. It is highly important to know the measurements which will probably ensure this result. The question has been discussed by Sédillot,§ who has arrived at the conclusion that the distance between the level of the first incision and that of the section of the bone should be equal at least to three fourths of the diameter of the limb, and may generally be made even greater with advantage. The great danger, particularly in a very long stump, is that the bone will be sawn too low, thus causing much trouble and anxiety in the after-treatment of the case, and ending perhaps in a conical stump. No harm can arise from a redundancy of soft parts, and much evil may result from not saving enough.

The rapid performance of this operation, in the way described, depends, as in the older circular method, upon the lax condition of the subcutaneous and intermuscular areolar tissue; if there has been much inflammation of the limb it will be difficult, if not impossible, to retract the soft parts sufficiently. The principal advantage of this mode of amputating is the facility which it affords for the perfect adaptation to each other, throughout their entire extent, of the cut surfaces both of muscle and of integument; a condition eminently favorable to extensive union by first intention. The sides of the wound are easily brought together, and may be kept in place by a few strips of adhesive plaster, while the deeper muscular surfaces are as easily held in contact with each other by soft compresses placed on opposite sides of the stump and confined by a

\* Dupuytren. *Leçons Orales de Clinique Chirurgicale*. 2me Ed., Paris, 1839, tome 2, page 333.

† Larrey. *Memoir on Amputation*.

‡ Desault. *Œuvres Chirurgicales*, par X. Bichat. Paris, 1796.

§ Sédillot. *Traité de Médecine Opératoire*. 2me Ed., Paris, 1853, tome 1, p. 327.

few turns of a roller. Excellent stumps may be made by this method, which, however, except in the manner of its performance, has less resemblance to the ordinary circular, than to the double-flap operation.

#### FLAP AMPUTATION OF THE THIGH.

*Method with two equal Flaps.*—This method was brought forward, at about the same time, by Vernale\* and Ravaton.† As performed by the latter surgeon, it is but a modified circular operation, in which no special covering of skin is preserved, and in which the denudation of the bone is effected by means of two longitudinal incisions upon opposite sides of the limb. In its results it closely resembles the operation of Celsus, with the advantage over it that the bone may be largely denuded with much greater ease, and is therefore more likely to be sawn at a sufficient height above the level of the section of the soft parts. Vernale operated by transfixing the thigh with a long knife, thus cutting the flaps from within outwards. The result is substantially the same as in the method of Ravaton, but, from the manner of cutting the flaps, they are more or less rounded and thinned at their free extremities, so as to admit of the margins of the skin being drawn together to form a covering for the end of the stump. In this operation the whole muscular substance of the limb is preserved for several inches below the point of section of the bone; the tissues, of which the flaps are formed, lie in their original position, and in most cases readily adhere to each other, forming a round and fleshy stump; the bone does not incline to protrude beyond the soft parts, because the deepest muscular fibres, which are attached immediately to the femur and therefore retract but little, are preserved of nearly the same length as the superficial muscles; and, finally, there are no angles of skin to form “ears,” as in the common circular operation.

The double-flap amputation is generally performed in one of two ways—either by transfixing the limb and cutting the flaps from within outwards, or by cutting them from without inwards. In the operation by transfixion, the point of the knife is plunged at once to the bone, with which it should be kept closely in contact as it is pushed onward in its course through the limb.‡ The knife is then carried downwards with a sawing motion, still grazing the bone, until about half the length of the flap has been cut; the edge of the knife is now to be turned obliquely outwards, and the section completed, thus giving to the extremity of the flap a curved outline. The other flap is formed in the same manner. An inexperienced operator may fail to transfix the limb symmetrically—that is, he may not make the knife come out through the skin at a point exactly opposite to that at which it entered. This is a matter of very little con-

\* Manheim, 1767.

† Paris, 1768.

‡ The object of this direction is to insure the preservation of the deepest muscular fibres, which are of very great importance as a protection for the end of the bone.



sequence, but a beginner may easily guard against it by first marking two dots upon opposite sides of the limb, or he may take the measure of the circumference of the thigh by encircling it equally with the thumb and fore- or middle-finger of both hands, and then allowing the left hand to remain in the same position, as a guide to the knife in the transfixion. Langenbeck\* cut both flaps from without inwards, first grasping with the left hand the tissues from which the flap is to be made. In a double-flap operation, described about the beginning of the present century by Professor Nathan Smith,† of Yale College, the form of the flaps was first marked out in ink, using as a guide a piece of paper cut in the form of a semi-circle, whose radius was equal to a fourth of the circumference of the limb at the point selected for the section of the bone. An incision was made in the course of the lines thus marked out, through the integuments first, which were drawn upwards by an assistant, and then obliquely through the muscles. After the soft parts were thus completely divided, the retractor was applied, and the bone sawn as high as possible between the flaps. In this operation the form of the flaps, owing to the tapering of the thigh, is almost exactly the same as in the method by transfixion as just described, but the separate division and retraction of the skin facilitates the coaptation of the soft parts and diminishes the danger of injurious tension upon the sutures. Another, and by no means the least, merit of this operation is the certainty with which it enables an inexperienced operator to make a good stump. In this operation the length of the flaps must depend in some degree upon the range of contractility of the muscles which enter into their formation, or, in other words, the nearer to the knee the amputation is performed the longer should the flaps be cut. As a general rule, the length of the flaps should be equal to three fourths or seven eighths of the diameter of the limb at the point where the bone is to be sawn. Great care should be taken to preserve the whole thickness of the muscles at the base of the flaps, and not to thin them except in the distal half of their length. The operation by transfixion is the most rapid, and is the one generally to be preferred, but there is no objection to either of the other methods. In cutting from within outwards, a little additional skin may be saved by drawing the integuments gently upwards towards the body before cutting them through. The flaps may be held in pretty good contact with each other by strips of adhesive plaster, but it is better, perhaps, to use a few sutures besides. The direction of the flaps may be varied almost indefinitely, and will sometimes be determined by the nature of the injury; as in the case of gun-shot fracture of the femur, in which the flaps should be so planned as not to include

\* Gottingen, 1820.

† Medical and Surgical Memoirs, by Nathan Smith, M.D. Edited by Nathan R. Smith, M.D. Baltimore, 1831, page 215, et seq.

in them the tissues lacerated by the ball. As a general rule, however, antero-posterior flaps are to be preferred to lateral ones, for in the latter case the end of the bone is in rather close proximity to the anterior angle of the wound, and may even be made to protrude by the action of the psoas-iliacus muscle flexing the femur upon the pelvis. The sciatic nerve is sometimes seen extending nearly to the extremity of the posterior flap; if this happens to be the case, it should be drawn out of its sheath and divided as high as possible, lest it become engaged in the cicatrix and cause a painful or tender stump.

The double-flap operation may be performed with nearly equal facility in all conditions of the tissues, from the state of perfect health, as in primary amputation for sudden injury, to the firm consolidation of the parts which results from the effusion and organization of inflammatory products. In the latter class of cases, therefore, it offers material advantages over any of the approved circular methods, both in ease and rapidity of performance and in the perfection of the immediate result. The form of the wound is favorable to the exact coaptation of the soft parts, whether we hope for union by first intention or by the adhesion of the granulating surfaces. The vascular connections of the flaps are not disturbed, and their nutrition is therefore more perfect than in the case of a cuff or flaps of integument only. The end of the bone is deeply buried between the flaps, but it does not press upon them, for it is protected by the projection beyond it of the deep muscular fibres. The stump bears neglect and bad usage during the after-treatment remarkably well, and will generally turn out well even in the hands of a very unskilful dresser.

#### FLAP AMPUTATION OF THE THIGH PERFORMED WITH A SINGLE FLAP, OR WITH TWO UNEQUAL FLAPS.

*Method with a single Flap.*—This method, invented by Lowdham\* about the middle of the seventeenth century, was at first employed chiefly in amputation of the leg. As performed in the thigh it is well described by Benjamin Bell,† who, however, did not often employ it; by William Hey‡ and Charles Bell,§ who advised it in certain exceptional cases, and by Sédillot,|| who adopts it as the regular operation, cutting the flap from the front of the limb. This method may be employed with advantage when the disease or injury for which we amputate has destroyed the tissues upon one side of the limb, leaving enough sound material to form a flap upon the opposite side; we may thus, in injuries by shell or by cannon-shot, occasionally preserve a much longer stump than

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\* Yonge. *Cursus Triumphalis*, &c., quoted by various authors.

† Benj. Bell. *Op. cit.* Vol. vi., page 398 et seq.

‡ William Hey. *Op. cit.* Page 531 et seq.

§ Charles Bell. *Illustrations of the great operations of surgery.* London. 1821. Pages 66 and 67.

|| Sédillot. *Op. cit.* Tome i., page 455 et seq.

could be made by a more symmetrical operation, a result which is often of very great importance in fitting and using an artificial limb.

The operation may be performed either by transfixion or by cutting from without inwards. The flap should be cut rather thin, in order that it may be easily bent over the face of the stump, and it must be large enough to cover the whole cut surface without stretching; in length and in breadth it should somewhat exceed the diameter of the limb at the point where the bone is to be sawn. After cutting the flap it is lifted up, and the section of the soft parts is completed by a single circular sweep of the knife. The attachments of the bone at the *linea aspera* should then be divided, the retractor applied, and the femur sawn an inch or two above the transverse section of the muscles.\* Care must be taken not to include any large vessel or nerve in the thickness of the flap, else there will be danger, in the former case, of secondary hæmorrhage, or, in the latter, of a painful or tender stump. In dressing the wound, the flap should be folded neatly over the end of the stump and retained in its place by a few sutures, aided by strips of adhesive plaster.

The single-flap operation, when performed in this manner, does not differ materially in principle from the common circular method; the chief difference consists in the form given to the covering of integument, by which the cicatrix is made to fall upon one side of the axis of the limb, where it is, perhaps, more in the way of pressure and of accidental injury than if it were central.

*Method with two unequal Flaps.*—The denudation of the bone in the last operation may be effected also by slitting up the soft parts for a couple of inches, thus lengthening the principal flap, and forming a second shorter flap upon the opposite side of the limb. For this purpose it is not necessary to make a separate incision, for we need only transfix the limb at a higher point and cut the long flap at once of the requisite additional length; the short flap may then be cut off at the same point at which its tissues would have been divided had the denudation of the bone been effected as in the common circular operation. The operation then resembles the double-flap method of Ravaton, with one of the flaps elongated and rounded at its free extremity, so that it may be bent over and made to fit the whole face of the wound. Such, in fact, is the well-known flap amputation below the knee, as performed by Liston, Fergusson and others, in which a long flap is cut from the tissues of the calf, and a short one in front.

If, now, the flaps have been cut of just the right length, they will fit admirably to each other, forming a well-rounded stump, with a lateral cicatrix; but it sometimes happens, in the course of the after-

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\* This manœuvre is of the same importance here as in the common circular operation, and for the same reason; the bone is to be protected by the projection beyond it of the muscles which are immediately attached to it, and not by attempting to make a thick cushion of soft tissues over its extremity.



treatment, that the flaps shrink, so as no longer to cover the bone. A common cause of this accident is the tension dependent on a deficient length of the flaps, and the remedy consists simply in cutting one flap or both of more ample dimensions. In the latter case, no change in their form will be required, but if any considerable addition is made to the length of the long flap only, it will be necessary to double it upon itself, and it will no longer fit neatly in its new position. This leads us to the operation lately introduced by Mr. Teale,\* which consists in making the long flap four times as long as the short one,† and cutting both with square instead of rounded ends. The wound is closed by doubling the long flap upon itself and securing its free extremity, by sutures, to the short one. Mr. Teale gives the important direction to make the long flap from "such parts as do not contain the larger bloodvessels and nerves," and it happens that "a flap so formed will be for the most part anterior in position as far as regards the general aspect of the body, but superior when the patient is in the recumbent posture"; this is, of course, a very "favorable position for allowing a free outlet for purulent and other discharges." Mr. Teale's operation certainly avoids tension, and gives an abundant covering of soft parts for the end of the bone, but it is by no means clear that the result is in any respect better than in the case of more nearly equal flaps. In fact, the shortening of the stump, owing to the extraordinary length of the long flap, which exceeds the short one by three eighths of the circumference of the limb, is, in the thigh, a sufficient reason for rejecting this method for all but a few exceptional cases.

#### COMPARISON OF THE RELATIVE MERITS OF THE DIFFERENT METHODS WHICH HAVE BEEN DESCRIBED.

Each of the methods which have been described has its advantages and disadvantages, which must be carefully weighed before we can decide between them. This is a task of some difficulty, for almost every surgeon becomes wedded to a particular operation which he learns to perform well, and it often happens that he attributes his success to the excellence of the general method which he follows, when in fact it is chiefly due to his own skill in executing it. A good surgeon will overcome the defects of a bad method, and thus produce better results than can be obtained by the best operation in the hands of a bungler. It is most important, then, that every operation should be excellent of its kind, and I have already attempted to show how this excellence may be obtained in each of the four principal methods which have been described. It is true, neverthe-

\* See abstract of Mr. Teale's paper in Braithwaite's Retrospect, Part xxxviii., 1859.

† The long flap is a perfect square, its length and breadth being equal to half the circumference of the limb at the place of amputation; the short flap is of the same width, but of only one fourth of the length of the long one. Mr. Teale marks out the flaps in ink and cuts them from without inwards, but they may be made more easily and with greater rapidity, in the thigh, by transfixion.



less, that there is almost always a choice between several methods, and it is important to know the general principles by which the choice is to be decided. Good stumps may be made by almost every method, but it is also true that no method affords perfect security against failure. There is little doubt, however, that in this respect some operations are better than others, both as making better stumps and more of them. All methods are not equally favorable to the formation of a good stump by the process of granulation, yet we can never be certain, in any particular case, that the cure will not have to be effected in this way. No operation, therefore, can be accepted as good unless it is well adapted to a cure by granulation; but it is none the less essential, in the majority of instances, to encourage union by first intention, by so shaping the incisions as to secure the accurate coaptation of the cut surfaces, both of the skin and of the muscles. Some methods admit of great precision in planning and executing the several steps of the operation, and may therefore prove especially valuable to an inexperienced operator, who on a sudden emergency finds himself compelled to amputate. Other methods are comparatively free from the danger of untoward accident occurring in the course of the after-treatment, and are therefore to be preferred in cases where the care of the patient must be entrusted to persons of doubtful competency. Extreme rapidity of performance is of less importance now than it was before the discovery of artificial anæsthesia, but there are still instances enough, especially in military surgery, in which the operator will have need of all the dexterity which he may possess.

In studying this division of the subject, I shall try to answer the following questions:—

1st. What constitutes a good stump, and what methods are best calculated to secure this result?

2d. What methods are best adapted to the process of healing by granulation, and which of them are also favorable to union by first intention?

3d. What methods are capable of the greatest precision in their execution, and are therefore most likely to insure a good stump in the hands of an inexperienced operator?

4th. What methods are least liable to after-accidents, and therefore require the exercise of the least skill and attention on the part of the dresser?

5th. What methods are the most rapid and easy of performance?

It has always been a great desideratum in amputations of the thigh to make a stump capable of sustaining upon its extremity a part of the weight of the body. This result was actually attained by Gooch, Alanson, Benjamin Bell, and by John and Charles Bell, who all amputated by the circular method as described in the early part of this paper. Benjamin Bell\* states expressly that the stump

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\* Benj. Bell. *Op. cit.*, vol. vi., p. 378.

of the thigh made by his method "admits of the patient resting upon it with freedom"; and Sir Charles Bell\* writes, "having occasion to see the amputation well performed by the double circular incision, the bone well covered, the cure rapid, the face of the stump broad and large, with a mere line marking the surface of the skin, I was convinced that the circular operation could not be improved." Of the nature of the best results attained by Larrey and Dupuytren, I cannot find any satisfactory account, but I believe that the plan of cutting the deepest muscular fibres at the same level as the section of the bone is essentially bad, and cannot but be prejudicial to the character of the stump; it is stated by Dr. King,† at one time house-surgeon (*interne*) at Hotel Dieu, that Dupuytren's stumps "were often conical in the wrong sense, and that sometimes even the bone was salient and afterwards exfoliated." The double-flap operation may be performed by transfixion, so as either to save or to sacrifice the greater part of the deep fibres, and in proportion as the former plan is adopted will be the degree of pressure which the end of the stump will sustain. If the incisions are made according to the rule established by Professor Nathan Smith, the deepest fibres will be preserved for an inch or more beyond the end of the bone, and this explains his statement‡ that, "for twenty years, during which he performed the operation a great number of times, he never made a bad stump." The successful result of the single-flap method will depend much, as has been already explained, upon the height at which the bone is sawn above the level of the section of the deepest muscles, and in the excellent operation of Mr. Teale, the deep muscles are preserved throughout the entire length of both flaps. It will be seen from these statements that I do not attribute the power of resisting pressure to any thickness of tissues which may be piled upon the end of the bone, but that my ideal of a good stump is rather one in which the soft parts form a ring-shaped cushion around the bone, and extending so far beyond it as to shield it and its cicatrix from chance knocks and to lift it from actual contact with any surface upon which the stump may rest. I believe that this general character may be given to the stump by either of the four principal methods already described, but that the circular operation of Dupuytren is that least adapted to this end. Such stumps are, however, comparatively rare, but the surgical mechanics have effected a great deal in the way of relieving patients from the consequences of bad amputations. It happens that many a stump which could not endure the direct pressure of a single pound upon its extremity, will nevertheless bear a pretty powerful tensile strain when applied to its periphery. This fact lies at the foundation of the modern art

\* Charles Bell. *A System of Operative Surgery, &c.* 3d edition. London, 1814. Vol. ii., pages 17 and 18.

† *Cyclopædia of Practical Surgery.* London, 1841. Page 142. Art., Amputation.

‡ Nathan Smith. *Op. cit.*, p. 222.

of making artificial legs; the upper part of the limb is fashioned into a conical socket, the sides of which are made to correspond, more or less exactly, to the tapering form of the stump, thus distributing the bearing over the greater part of its lateral surface and letting the end of the stump hang free in the centre. The effect of this arrangement is to draw upon the cicatricial tissues which bind the skin and other soft parts to the end of the bone, at the same time that the immediate coverings of the bone are relieved from all pressure, and in this way a handsome and pretty servicable limb may be fitted to a very bad stump. In other cases, when the stump is very short, or very tender, it is allowed to hang loose in the socket, and the whole weight of the body is supported upon the tuberosity of the ischium. Great as have been the triumphs of modern mechanical surgery, there is still no doubt that a stump which is fitted to bear considerable pressure upon its extremity will also best sustain the weight of the body in the conical socket of an artificial limb; I think, therefore, that Mr. Teale deserves our gratitude for bringing forward a method whose results are eminently calculated by contrast to compel the attention of surgeons to the great defects in many of the common methods of amputating.

To promote the process of healing by granulation, either the incisions should be so planned as to allow the opposite surfaces of the wound to lie loosely in contact with each other, in order that adhesion may take place speedily between them; or else, if the wound is to be left entirely open, as was the practice of the older surgeons who employed the circular method, the bone must be sawn very much shorter than the muscles, and at the same time the skin must be preserved of good length that it may be the more readily drawn inward towards the centre of the stump by the contraction of the cicatrix. The former of these conditions is well fulfilled in the flap operations, and less perfectly in the circular method of Dupuytren; the latter, in the common circular operation. The flap operations and the circular of Dupuytren are eminently favorable to union by first intention; the common circular is less so. For the precision with which the work is laid out before hand, the preference must be awarded to the double-flap operation of Professor Nathan Smith, and the method of Mr. Teale with rectangular flaps; in both of these methods the flaps may also be cut by transfixion after they have been marked out in ink upon the limb. In the common circular operation, however, it is not difficult to remember to retract the skin until a breadth of fascia has been uncovered equal to half the diameter of the limb, and to denude the bone before sawing it, for a couple of inches above the plane of the section of the muscles. In this respect, also, the circular operation of Dupuytren is deficient, as its proper performance depends mainly upon an accurate eye and correct judgment at the moment of the incisions.

The local accidents which may result to a greater or less extent



from a defective manner of operating, are inflammation and sloughing, as a consequence of tension of the soft parts; abscesses and sinuses, dependent in part on a bad form of the coverings; conical stump and necrosis, from excessive muscular retraction; and hæmorrhage, which has been supposed to depend in part upon the extent of the wound and upon the oblique section of the arteries. Some of these accidents may be averted by proper treatment, but if neglected, may become truly formidable. Tension of the coverings is a very common cause of pain and inflammation in the early stages of the treatment, and often leads to extensive loss of substance by sloughing. The best safeguard against it consists in preserving a large quantity of skin and muscle, for it is hardly ever the case that any inconvenience results from too ample coverings, however redundant they may appear at the time of the operation. Sinuses and collections of pus are sometimes caused by the too close confinement of the edges of the wound, while the deeper tissues are allowed to lie separated from each other, forming cavities for the lodgment of blood and matter. This is very apt to occur after the operation with a single posterior flap, in which case the weight of the flap drags upon the sutures in front, and tends to form a large pocket in a situation unfavorable to the escape of discharges. Conical stump and exfoliation of the end of the bone, as dependent upon original deficiency of the soft parts, or upon their excessive retraction, has been already treated of in the description of the common circular operation, and it need only be repeated in this connection, that the surest preventive of this unfortunate accident consists in the preservation of such of the soft parts as are themselves least prone to retract, that is, the deep muscular fibres which arise from or are inserted into the femur near its sawn extremity. The occurrence of hæmorrhage within a few hours after the operation is very frequent after secondary amputations performed in the neighborhood of inflamed parts; in such cases all the tissues of the limb are congested with blood, and the number of bleeding vessels is often very large, so that it may readily be believed that the larger the wound, the greater the probability that some of the dilated vessels may escape being tied. The danger of hæmorrhage from this cause may be greatly diminished, however, by leaving the wound open to the air for a few hours until its surface has become "glazed."\* Of the different operative methods which admit of the perfect closure of the wound, the circular operation of Dupuytren exposes the least extent of cut surface; next to this, and exceeding it but very slightly, comes the double-flap operation of Vermale, Langenbeck and Nathan Smith. The common circular method exceeds these in the ratio of about three to two; and the operation of Mr. Teale, with

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\* This "glazing" of the cut surfaces seems not to interfere with the healing of the wound by primary adhesion, and it indirectly promotes this result by the increased security which it affords against the separation of the flaps by coagula of blood.



rectangular flaps, exposes a greater extent of cut surface than any of the others, bearing the ratio to the first of  $3\frac{1}{2}$  to 2.\* The oblique division of some of the soft parts in the flap operations can only affect the form of the section of the principal arteries, which, from their size and known position, can be secured without difficulty; the smaller vessels, whose enlargement by inflammation is the chief cause of this form of hæmorrhage, are very irregular in their course, and are perhaps as likely to be cut off obliquely in the circular as in the flap methods. It is, of course, possible, occasionally, to split the femoral artery in transfixing the limb, but a very slight acquaintance with the anatomy of the thigh will enable the operator to avoid the vessel by varying slightly the direction of the flaps. Out of a considerable number of stumps of the thigh which had been wholly neglected for a week or two after the operation, I have seen by far the best results in cases in which the amputation had been performed by the double-flap method. I have little doubt, however, that under similar circumstances, equally good results may be obtained by other methods, provided only that the operation, whether flap or circular, is good of its kind. I have seen two or three very handsome stumps made by the method of Dupuytren, but they had received excellent care and had healed by first intention. I have seen many miserable failures in amputations performed by circular incisions, but I think that, in these cases, the fault lay rather with the operator than with the method.

\* The relative extent of the cut surface is pretty accurately shown by the following demonstration, based upon the assumption that the thigh is a cylinder:—

Representing the radius of the cylinder by  $r$ , let  $s$  stand for the area of the cut surface in the common circular operation,  $s'$  in the circular of Dupuytren,  $s''$  in the double-flap operation, and  $s'''$  in the operation of Mr. Teale.

In the common circular operation, the area of the cut surface is equal to the area of the cross section of the cylinder, plus the area of the inner surface of the cuff, plus the muscular surface exposed by the denudation of the bone. The thickness of the tissues of the cuff is about equal to half the diameter of the bone; the cut surface, therefore, will be equal to the area of the cross section of the cylinder, plus the area of the outer surface of the cuff, which makes

$$s = \pi r^2 + 2\pi r^2 = 3\pi r^2$$

In the circular operation of Dupuytren, the cut surface has nearly the form of a hollow cone, the circumference of whose base is equal to the circumference, and whose oblique height is about equal to the diameter of the cylinder. The area of this cone is half the product of its oblique height by the circumference of its base, which gives

$$s' = \frac{2r + 2\pi r}{2} = \frac{4\pi r^2}{2} = 2\pi r^2$$

In the double-flap operation, as it is usually described, assuming that the bone is sawn at the same level as in the circular operation of Dupuytren, the form of the cut surface will be that of two semi-ellipses, which are together equal to an ellipse whose conjugate and transverse diameters are  $4r$  and  $2r$ , and whose area is  $2\pi r^2$ . If, however, the operation is performed as described in this paper, the area of the cut surface will be greater in the ratio of about 6 : 5. This gives, therefore,

$$s'' = 2\pi r^2 \text{ or } 2\frac{2}{5}\pi r^2$$

In the operation of Mr. Teale, the area of the cut surface is equal to the area of the cross section of the cylinder, plus the area of the lateral surface of the long flap, plus the area of the lateral surface of the short flap, therefore

$$s''' = \pi r^2 + 2\pi r^2 + \frac{1}{2}\pi r^2 = 3\frac{1}{2}\pi r^2$$

Comparing the several values of  $s$ ,  $s'$ ,  $s''$ , and  $s'''$ , we have the proportion

$$s : s' : s'' : s''' = 3\pi r^2 : 2\pi r^2 \text{ or } 2\frac{2}{5}\pi r^2 : 3\frac{1}{2}\pi r^2 = 3 : 2 : 2 \text{ or } 2\frac{2}{5} : 3\frac{1}{2}$$

For ease and rapidity of execution, the double-flap operation by transfixion, and, in cases suited to it, the circular of Dupuytren, stand first; the processes of Nathan Smith and of Mr. Teale, and the common circular method, involve a more deliberate dissection, and therefore require more time for their proper performance.

The choice, then, of the operative method best suited to any particular case, may generally be decided by a reference to the following points:—

1st. In cases where the injury or disease is confined to one side of the limb, the method with a single flap, or that of Mr. Teale with unequal rectangular flaps, is especially indicated, and its adoption may result in a saving of several inches in the length of the stump, which would be sacrificed by a more symmetrical operation.

2d. If the incisions are to be made in tissues consolidated by inflammation, the operation can be performed better and with greater ease by flaps than by either of the circular methods.

3d. If there is a probability that the after-treatment will have to be conducted under unfavorable circumstances, or by unskilful persons, the circular operation of Dupuytren is that least likely to give a good result.

4th. If the operator himself be unused to amputating, he will do much towards ensuring a good result by first marking out the outlines of the flaps, or, if he adopts the common circular operation, by pausing to estimate the progress of his work, both after the retraction of the cuff of skin, and before sawing the bone.

Finally, if the operator is expert, the parts healthy, and all the circumstances of the case favorable to a speedy union, it matters but little, comparatively, which method is adopted. If, however, I were called on to name the method which is applicable to the greatest number of cases as they occur in practice, I should have little or no hesitation in awarding that distinction to the double-flap operation performed by transfixion, as I have described it; and I would especially advise an inexperienced operator first to mark out the flaps, in the manner taught by Professor Nathan Smith.

*Two or three especial points deserve notice in connection with Amputation of the Thigh.*

A bad position of the patient upon the table may give rise to great embarrassment in the retraction of the soft parts. All trouble from this cause may be avoided by drawing the body well down, so that the nates may rest upon the edge of the table.

The position of the limb during the operation is a matter deserving of more attention than is usually bestowed upon it. It is well known that after amputation of the thigh the stump inclines to turn upward, through the action of the psoas-iliacus muscle. In proportion as this elevation takes place, the muscles on the back part of the thigh (the long head of the biceps, the semi-membranosus, semi-tendinosus, and adductor magnus), which all arise from the tube-

rosity of the ischium at a point about two inches diagonally behind and below the centre of motion of the head of the femur, are drawn away from the end of the bone, while the vasti and crureus, which arise from the front and sides of the femur, are not at all relaxed by the change in position. This fact, which has been long recognized, has led to the direction, either to leave the soft parts longer behind than in front,\* or to confine the thigh by straps in a horizontal position during the course of the after-treatment.† It is an excellent plan, in this and in some other amputations, to operate upon the limb in the same position which it is likely to assume during the after-treatment, and this position, in the case of the thigh, will be that of partial flexion on the body. The thigh may be still farther elevated, before sawing the bone, with the advantage of greatly facilitating the separation of the muscular and tendinous attachments at the *linea aspera*.‡

The dread of lacerating the periosteum has led to the precept never to apply the saw until this membrane has been divided by a circular sweep of the knife. This is a necessary precaution in very young persons, in whom the periosteum is easily detached from the bone, but is superfluous in the case of adults. It is of much greater importance carefully to avoid denuding the bone above the point of its section, even if we have to divide a few muscular fibres with the saw.

#### HÆMORRHAGE.

*The control of the hæmorrhage during the operation* is effected either by pressure upon the femoral artery, or by tightly encircling the whole limb with a fillet; or the two methods may be combined, as is the case in the tourniquet of Petit, which is now in common use. The old method of tying the fillet tightly around the limb has the great disadvantage of acting slowly, thus compressing the veins before the arteries, and allowing the whole limb to become congested with blood before the operation is commenced. The introduction of the "garrot," however, by Morel, rendered the method nearly perfect. The fillet is tied loosely around the thigh, and is tightened, at the very instant of making the first incision, by twisting with a short stick placed beneath it. The action of the "garrot" is almost instantaneous, and it is powerful enough completely to arrest the circulation in all the vessels, both great and small. The tourniquet of Petit is a strap adjusted by a buckle, and capable of being tightened by turning a screw, which at the same time compresses the main artery by means of a wooden pad. The action of this instrument is slower and less powerful than that of the "garrot," and it allows the limb below it to become engorged with blood, without affording absolute security against arterial hæmorrhage. The "compressor" of Dupuytren consists of two pads connected with each other by a

\* Malgaigne.

† B. Bell. Liston.

‡ Charles Bell. *Great Operations*, op. cit., p. 60.

strong arc of steel. The larger pad, which is made flat, is applied to the side of the limb opposite to the main artery, and serves as a point of resistance to the smaller pad, which is forced down upon the vessel by turning a screw. This instrument does not prevent the return of the blood through the veins, and it may be applied, as may also the tourniquet of Petit, to compress the femoral artery against the horizontal ramus of the pubes where it emerges from the pelvis.

All instruments for the compression of the femoral artery have the disadvantage that they cannot be easily applied so high as is often desirable, and when placed too near the point of amputation they interfere with the proper retraction of the soft parts, if indeed they do not become loose or slip off altogether at the very moment when they are most needed. They are therefore better adapted to amputations in the lower than in the upper half of the thigh, and they interfere less with the performance of the operation by flaps than by the circular methods. The best method of compressing the femoral artery is by the fingers of a thoroughly competent assistant. Slight pressure suffices, and it is applied at the exact point where the pulsation of the vessel is felt. The pressure may be kept up, with but little fatigue, for an hour or more, if necessary, and it may be relaxed or resumed in an instant. The compression of the femoral artery may be made most conveniently against the pubes, and at this point it offers no impediment to the retraction of the soft parts. In the absence of a competent assistant, the "garrot," or handkerchief and stick, is probably a more efficient instrument than the common tourniquet.\*

Every surgeon has observed that, at the moment of making the incisions, quite as much blood often flows from the vessels of the severed limb as from those which remain connected with the heart. The hæmorrhage from this source is often greatly increased by the unskilful manner in which the tourniquet is applied; but even under the most favorable circumstances the loss of blood will be equal to the quantity originally contained in the limb, in addition to that which escapes, owing to the imperfect suspension of the arterial circulation. The idea of emptying, in part, the vessels of the limb before the operation, is found in the writings of Prof. Nathan Smith† and of Sir Charles Bell. The former surgeon proposed either to elevate the limb above the level of the body, or to compress the main artery for a few minutes before tightening the handkerchief, which he used instead of the tourniquet. Sir Charles Bell's‡ plan is more efficient; it consists in applying a roller firmly and evenly to the whole limb before operating, by which course "the veins are emptied into the general system, and blood is saved instead of being with-

\* See Nathan Smith, *op. cit.*, p. 223. Also Dupuytren, *Leçons Orales*, tome 2me, p. 381.

† *Op. cit.*, page 224.

‡ Charles Bell. *Great Operations*, page 58, note.



drawn." This application of a roller to the limb may be of the greatest service in a very exhausted state of the patient, and there is no good reason why it should not be generally adopted in the case of the larger amputations.

*For the arrest of the hæmorrhage after amputation*, very many methods have been employed at different times, but they may all be divided into two classes, according as they are applied to the main artery only or to the whole cut surface. Of the former methods the ligature deservedly stands first. The common direction is to draw out the end of the artery from its sheath by forceps\* or by a tenaculum, and to tie it with strong silk or linen thread. In a healthy state of the tissues this is easily effected; the artery is connected with the surrounding parts by lax areolar tissue, and can readily be drawn out for half an inch or more, retracting again into its sheath as soon as it is released. In a limb, however, which has been the seat of inflammation, this areolar tissue is often found consolidated by a deposit of coagulated lymph, which glues the artery firmly to its sheath. In this state of the parts, which is frequently observed in secondary amputations, it is often impossible to isolate the artery,† and the only alternative then is to include some of the surrounding tissues in the ligature, taking care, however, not to tie up any large nerve. This "mediate" ligature is best applied with the aid of a curved needle or tenaculum. The point of the instrument is passed into the face of the stump a short distance from the mouth of the vessel, and is carried across in such a way as to transfix the walls of the artery, emerging on the other side; the ligature is now tied firmly behind the tenaculum, and thus the vessel is constricted just above the point where it has been transfixed. Applied in this way, the ligature is more liable to slip off than when it is placed immediately upon the artery, and the larger the mass of flesh in which is encircled by the thread, the greater will be the probability of its shrinking under the pressure and allowing the ligature to become loose. In cases where it is necessary to trust to this method for the closure of the femoral artery, it may be well to use a small curved needle instead of the tenaculum, tying the ligature behind it, and leaving the needle in its place for several days; the needle might be drawn out at any time by means of a thread passed through its eye. The "mediate" ligature is especially useful in the case of the smaller muscular branches, which are not easily isolated and at the same time become very soon obliterated. The thread used for ligatures should be strong enough to bear considerable tension, in order that it may sink a little into the walls of the vessel, and thus afford the greater security against slipping. A very fine ligature is seldom of sufficient strength to constrict a large artery, and is liable, also, to cut through the tissues; a coarse cord,

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\* Paré.

† Liston. Elements of Surgery, Am. Ed., 1837, p. 518.

on the other hand, cannot easily be tied with sufficient firmness about a small vessel, especially if the so-called surgeon's knot is employed. The size of the ligatures should bear a certain relation, therefore, to the diameter of the vessel, ranging from coarse surgeons' or saddlers' silk, or coarse linen thread, for the largest artery, to fine sewing silk for the smaller vessels. It would probably afford additional security against slipping when the knot is tied, if the thread, instead of being simply waxed, were prepared beforehand by soaking it in melted wax, or in a mixture of wax with a little pitch or resin.

The proper disposition to be made of the free ends of the ligature has long been a subject of dispute, and is not yet altogether settled. In an open wound, healing by granulation, the ligatures are thrown off with the discharges long before the process of cicatrization is far enough advanced to be injuriously affected by their presence. In such a case, therefore, it is best to cut off both ends of the ligature pretty close to the knot. In cases, however, where union of the soft parts takes place by first intention, the knots often become enclosed in the tissues and give rise to irritation which may continue for a long time, until the offending thread is discharged by the formation of an abscess. To avoid trouble from this cause, one end of each ligature is generally left projecting between the lips of the wound, in order that the knot may be drawn out as soon as it becomes detached from the mouth of the artery. A few surgeons still adhere to the bad practice of cutting off both ends of the ligature close to the knot;\* others have recommended fine catgut or shreds of split tendon, upon the erroneous supposition that such substances become speedily absorbed when buried in living tissues.

Torsion, or violent compression of the walls of the artery, is often employed with advantage for small vessels whose muscular coat is easily stimulated to contraction, but it is both troublesome and unsafe when applied to the larger arteries.

Dr. Simpson,† of Edinburgh, has recently called attention to a very useful invention which he calls "acupressure." It consists in compressing the artery at a single point of its length by means of a strong pin of about the size of an ordinary knitting needle. The pin is thrust through the skin and other tissues of the stump on one side of the artery, in such a direction that its point passes quite near the vessel, against which it is made to press pretty firmly by suddenly changing its direction and thrusting it onward until it emerges on the other side. The pressure should not be very powerful, for a very moderate force suffices to control the circulation in the artery,

\* Almost all authorities concur in recommending the removal of one end only of each ligature, the practice of cutting them short having been thoroughly tested by Lawrence, Liston and others, who all unite in condemning it. Very lately, however, Heyfelder has denounced the custom of leaving one end as "neither necessary nor useful, but altogether injurious and wholly unjustifiable." (See the New Sydenham Society's Year Book for 1860, page 271.)

† *Edinburgh Medical Journal*, January, 1860.

and any unnecessary compression would only cause inconvenience, and might endanger the vein or nerve. The theory of acupressure is aptly illustrated by Dr. Simpson, who compares the vessel to the stem of a flower fastened by a pin to the lapel of a coat. This method, which is very easy of application, seems destined to more extended use in surgery, and may even deserve a trial as a substitute for the ligature in the treatment of aneurism. Acupressure seems hardly indicated in ordinary cases of amputation, and is not applicable to secondary amputations in inflamed or congested tissues, but in the treatment of secondary hæmorrhage it promises to render good service.

The actual cautery has been properly abandoned for very large vessels, owing to the uncertainty of its immediate action, and the very great liability to the recurrence of dangerous hæmorrhage upon the separation of the eschar. For small arteries, the hot iron is both efficient and easy of application, and might be employed with advantage much oftener than is now the fashion. Caustics, such as the old "button of vitriol," &c., are more painful and less efficient than the actual cautery, and it is almost impossible to confine their action to the bleeding point.

The alleged advantage of many of these substitutes for the ligature is that they do not interfere with union by first intention by interposing any foreign substance between the opposite surfaces of the wound. This advantage, however, is unreal in the case of amputations, for the sharp end of the bone always excites more or less of inflammation, attended by suppuration in the very deepest part of the wound; the ligatures, therefore, do good, for they prevent the formation of sinuses and abscesses by keeping open a free passage for the discharge of the matter. It will generally be found most convenient to collect the several ligatures into a single bundle, bringing them out together at the most dependent part of the wound. It is better to leave but one end to each ligature, and it is well to distinguish the ligature of the main artery from the others by tying a knot in it.

Two cases are occasionally met with in practice, in which it is impossible to close the artery by the ligature. When the nutritive artery of the tibia is divided a little below the point at which it enters the bone, it sometimes throws out a smart jet of blood which does not readily stop of itself. In this case compression with the finger, plugging the hole with wax, &c., have been proposed, but the simplest and most effectual plan is that adopted by Mr. Liston, which consists in driving in a small peg of soft wood and withdrawing it after a day or two by means of a bit of string tied to it. The other case occurs occasionally in old persons, in whom the walls of the arteries are often indurated by calcareous deposits. The most obvious course to pursue in this condition of the vessels, would seem to be the insertion of a plug into its open mouth, tying the ligature over it.

Hæmostatic agents which are applied to the whole surface of the wound, may be divided into two classes, according as they promote or impede the accomplishment of union by first intention. Of the latter class are the ancient methods of searing with a hot iron, cutting the soft parts with a red-hot knife, dipping the end of the stump in hot pitch or oil, strewing the raw surface with astringent or escharotic powders, binding agaric or sponges tightly against the bleeding surface, &c. &c. To these may be added the plans recently put forward of dividing the soft parts by the galvanic cautery,\* or by the extemporaneous ligature (ecraseur);† also, the employment of powerful styptic solutions of sesqui-chloride of iron, &c. Some of these methods may be adopted with advantage in certain cases of secondary hæmorrhage, but they ought never to be used in any case in which union by first intention is possible.

Of the local applications which may arrest hæmorrhage without impairing the chances of speedy union, the free use of cold water and the exposure of the raw surface to the action of the air, are among the most important. Dashing or sponging the wound freely with cold water causes the immediate contraction of the mouths of the smaller vessels, but bleeding is very apt to recur whenever reaction takes place. The use of cold applications, therefore, to be effectual, must be continued for a considerable time, and great care must be taken to protect the patient from the discomfort of cold and wet bed-clothes. The exposure of the open wound to the air acts in part, doubtless, by the cooling effect of evaporation, but its chief efficacy is probably due to the stimulating action of the oxygen upon the tissues. A wound thus exposed for a time to the air, is very much less likely to bleed after it is done up than if treated by cold applications. The formation of clots between the opposite cut surfaces, which is one of the greatest obstacles to their early union, is prevented, and the dressings, when once applied, seldom require to be disturbed for several days. If sutures are used, they may be inserted at the time of the operation, while the patient is yet under the influence of chloroform, and loosely knotted together until the time arrives for finally adjusting them.

The local use of strong alcohol as a styptic, has been lately advocated in France.‡ When used of the strength of 36° Cartier (=89.6°), it coagulates the albumen on the surface of the wound, forming a greyish-white pellicle, and stops the hæmorrhage from the small vessels. It is also said to hasten the secretion of plastic lymph and to prevent diffuse suppuration by coagulating the albumen of the cellular tissue. At first view, it would seem that the contact of so powerful an agent with a fresh wound would almost of necessity cause the death of its surface, and thus entail a more or less tedious suppuration. Experiments have proved, however, that

\* Middeldorpf.

† Maisonneuve.

‡ Alcohol and Alcoholic Preparations in Surgery, &c. By F. J. Batailhé and Ad. Guillet. Paris. 1860.



strong alcohol may be applied to fresh wounds without exciting inflammation, and it seems indeed to favor union by first intention, by thoroughly arresting the hæmorrhage from the small vessels.\* Alcohol is moreover powerfully antiseptic, and offers many advantages over the solution of hypochlorite of soda as an application to sloughing and bleeding sores.

*Primary Hæmorrhage after Amputation* is a very common occurrence, and depends upon the imperfect closure of the smaller vessels, or possibly upon the accidental loosening of a ligature. Under the stimulus of the knife and of the exposure of the cut surface to the air, the muscular walls of the smaller vessels contract so as speedily to arrest the flow of blood from them. This contraction generally continues until coagula have formed, and the natural processes of repair have commenced. In other cases, however, the first arrest of the bleeding is rather the result of faintness than of arterial contraction, and the recovery of the patient from the shock may be attended by a renewal of the hæmorrhage. The best preventive of this accident, as has been already stated, is to leave the wound open to the air until its surface becomes glazed, and if bleeding recurs after the wound has been dressed, it should be immediately opened, so as again to expose its whole surface. If the bleeding artery can be found, it should be tied or twisted; but if the flow of blood ceases of itself, as it often does in such cases, the wound should be left open for an hour or two to glaze. Should the ligature slip off from the main artery, it should be secured again in the wound, or by an acupressure pin passed through the flap above; in either case, however, the wound should be freely opened, lest the cure should be impeded by the presence of clots between the cut surfaces.

The term *secondary hæmorrhage* should be confined to those cases in which bleeding occurs from the failure of the natural processes by which the permanent closure of the vessels is effected. It often occurs at the time of the separation of the ligatures, and it may happen at any time by the gangrene or ulceration of the walls of the vessels. At this period a considerable part of the wound may have already healed, and its surface will have become so changed by the morbid action as to make it very difficult to find the end of the artery; and even if it could be easily found, its altered and friable walls are no longer fit to receive a ligature. In this state of things it is folly to tear or cut the wound open in the attempt to apply a ligature to the mouth of the artery. Stuffing the wound with lint or sponges may arrest the hæmorrhage for the moment, especially if aided by the use of styptic solutions, such as the sesquichloride of iron. The actual cautery is even less certain in secondary than in primary hæmorrhage from large arteries. All such local measures

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\* Alcohol and Alcoholic Preparations in Surgery, &c. Pages 4 and 20.

for the arrest of secondary hæmorrhage are extremely uncertain, and have besides the great disadvantage of interrupting the healing process.

Secondary hæmorrhage may also be treated by compressing the artery above the wound where its walls are probably healthy. In a few cases it may be sufficient to maintain constant pressure with the tourniquet for several days, until a clot has formed in the mouth of the artery, but as a general rule more decided measures are necessary. Under these circumstances, the choice must be made between acupressure and the ligature of the arterial trunk. Acupressure is readily applied at any desired point in the course of the vessel; it inflicts very slight injury upon the limb, and may therefore be repeated several times if it should be necessary. The needle should be passed into the skin, at a distance to one side of the artery somewhat greater than the depth of the vessel below the surface, and its point carried as nearly as possible beneath the artery. The outer end of the needle is then depressed, so as to compress the artery between the needle and the skin, and the needle is then pushed onward until its point emerges through the skin on the other side of the vessel. Should the pressure of the needle be insufficient to control the bleeding, its action may be aided by a few turns of the twisted suture taken over a compress laid along the course of the vessel.\* Acupressure should be practised as near as possible to the open end of the artery, for fear of the continuance of the hæmorrhage by anastomosing branches. This method promises to render excellent service in the treatment of secondary hæmorrhage, and should be fairly tried before undertaking the much more serious operation of tying the femoral artery. Should acupressure fail, we have still the resource of laying bare the artery and tying it, which should be done either very near the end of the stump, or else above the point of origin of the larger collateral branches. Thus in amputations in the upper part of the thigh, it will probably be safest to tie the femoral artery above the origin of the profunda, and in any case, if a first ligature placed near the end of the stump fails to arrest the hæmorrhage, there need be but little fear of danger in tying the artery again at a higher point.†

After the hæmorrhage has been arrested, the chief care of the surgeon should be directed to the promotion of a healthy process of repair by granulation. It is not advisable, as a general rule, to separate the flaps, or in any way to disturb the existing adhesions; but if partial union has taken place in such a way as to form cavities for the lodgment of matter, they should be freely opened at the

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\* A needle with a curved point, such as has been used by Mr. Startin in the treatment of varicose veins, would probably be better for this purpose than the straight acupressure needle used by Dr. Simpson. (See Braithwaite's Retrospect, Vol. xlii., page 161.)

† See Nélaton, *Pathologie Chirurgicale*, Tome Ire, page 235. Also for a discussion of the question of the high ligature of the femoral artery, see a paper by Mr. Porter in the *Dublin Quarterly Journal* for November, 1860, and Braithwaite's Retrospect, Vol. xliii., page 124.

most dependent part, and the walls of the cavity kept in contact by means of a roller and compresses carefully adjusted at every dressing. If the hæmorrhage has been the result of rapid ulceration or sloughing, it is probably dependent upon impaired constitutional power, and its recurrence is to be opposed by a generous diet and tonic remedies.

#### DRESSING AND AFTER-TREATMENT OF STUMPS.

Before considering the subject of dressings, it may be well briefly to review the history of the processes of repair so far as they are concerned in the healing of the wound made by amputation. First of all, it must be remembered that we have to deal with two totally distinct classes of tissues:—1st, The soft parts, consisting of skin, areolar tissue, muscle, and dense fibrous tissue, which may all heal by the processes of immediate union, primary adhesion, adhesion of granulating surfaces, or by the slow process of granulation and cicatrization; and 2d, the bone, in which, even in subcutaneous injuries, as in simple fracture, the process of repair does not begin until after eight or ten days\* and upon whose sawn extremity granulations do not appear until the tenth day or later.† Now it is evident that the soft parts may unite by either of the three methods first mentioned, before the slightest change has taken place in the bone, for the soft parts probably never unite with the compact tissue of the sawn end of the bone by any much speedier process than the slow one of granulation. It is idle, therefore, to talk of the complete cure of a stump by first intention, for the sharp end of the bone will act for a considerable time as a foreign body, and will always excite more or less of suppuration in its neighborhood.‡ We must not, therefore, be over anxious about the ligatures, for they really act beneficially by keeping open a convenient outlet for the discharges, which might otherwise burrow among the muscles and at last find vent in an abscess.§

\* Paget. Lectures on Surgical Pathology. Lecture XI., on Repair of Fractures.

† Ibid. Lecture IX., on Healing by Granulation.

‡ See Sédillot. Op. Cit. Tome Ire, page 344. Also Dupuytren, Leçons Orales, tome 2me, p. 403 et seq.

§ There has been much unprofitable discussion during the present century between the partizans and opponents of the practice of healing stumps and incised wounds generally by first intention. The early advocates of this plan of treatment in amputations were English surgeons who practised chiefly in the provinces, amid favorable atmospheric and hygienic influences. The chief opponents of early union were found among the distinguished surgeons of Paris, who have always had to contend against the enormous sanitary evils which exist in the great public hospitals of that city. As often happens, in such disputes, both parties were right, and each adopted that line of practice which local experience had shown to be best. In country practice, and even in towns of moderate size, wounds generally heal promptly and without much suppuration. In large cities, on the other hand, and especially in city hospitals, complete union by first intention is excessively rare, and the union of the skin and superficial parts only may do mischief, by confining the products of the suppuration of the deeper tissues. In the case of dressing after amputation, the whole point at issue is, whether we ought accurately to close the whole wound by sutures and plasters, or keep a channel open for the escape of the pus, by interposing a narrow strip of linen between the opposite surfaces. Even this difference is more in theory than in practice, for in a great many cases the ligatures act as a seton in maintaining an outlet for the discharges, and it matters very little whether we trust to the ligatures alone, or add to the size of the bundle by a roll of char-

In dressing a stump, then, we must aim to fulfil two distinct indications:—1st, To promote the union of the soft parts; and, 2d, to protect the soft coverings from the sharp end of the bone.

I have already insisted upon the importance of so arranging the successive steps of the operation as to secure a just relative proportion between the different tissues left for the purpose of covering the bone. The bone must be thoroughly protected by the preservation of a sufficient length of the deep muscles, which should, in turn, be covered either by integument or by a thin flap composed of skin and muscle. According as these conditions have been fulfilled, will be the possibility of effecting a cure mainly by first intention. The soft parts should be so ample as to admit of the complete approximation of the opposite cut surfaces throughout their entire extent, and that without exposing them to the slightest tension. Tension of the coverings is one of the most fruitful causes of failure in the attempt to secure union by first intention, and the irritation which it produces is often the beginning of a formidable train of accidents. Rather, therefore, than to expose the soft parts to any strain in the early dressings, the wound should be left open, according to the precepts of the older surgeons, and allowed to heal by cicatrization from the circumference to the centre.

In order to promote the union of the soft parts, they must be held in accurate contact with each other, skin with skin and muscle with muscle. This contact with the muscles should be aided by moderate pressure, applied to opposite sides of the stump, near its extremity, by means of soft compresses and a roller.\* The margins of the skin should also be brought together and held in place by the interrupted or twisted suture, or by strips of plaster. In circular amputations the wound can, in most cases, be easily closed by strips of plaster alone; but in the flap operations, a few points of suture are generally employed in addition. If the interrupted suture is used, the threads may be inserted at the time of the operation and loosely knotted together until the time arrives for finally adjusting them. The twisted, or hare-lip suture, holds the parts more firmly in place than any other, but its very firmness may become a source of serious danger should swelling or retraction of the soft parts take place. The small spring forceps, called "*serres fines*," have at least the advantage that they slip off before the ten-

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pie or a strip of linen. No author at the present day, so far as I know, advises a return to the ancient practice of leaving the wound entirely open and waiting for it to heal by the gradual drawing in of the integuments, from the circumference to the centre, by the contraction of the cicatrix. The difference between the hygienic influences of city and country can hardly be too strongly presented, for it has a most important bearing, both upon the treatment to be adopted as well as upon the probable result of a surgical operation. Thus many operations which are attended with very considerable danger in the practice of the great metropolitan hospitals, seem to be almost unattended by serious risk when performed in the country. A notable illustration of this point is found in the statistics of lithotomy as performed in the Western United States and the hospitals of Paris and London.

\* In the operation with a single flap, the nature of the support given to the flap must depend upon its form and position; in Mr. Teale's operation no such support is needed.



sion can become excessive. If sutures are used they must be carefully watched, and removed upon the first sign of their causing pain or irritation. As a general rule they should be supported by strips of plaster placed between them, taking care, however, not to cover the wound so closely as to confine the discharges. Plasters are, on the whole, safer than sutures, especially if the case is to be left to the care of unknown or unskilful persons, and they can almost always be applied with sufficient exactness if the operation has been even tolerably performed.\* If the common adhesive plaster (*emplastrum resinæ*) is used, it should be freshly spread, as it is apt to become brittle and non-adhesive when old. As commonly prepared, it is spread upon heavily-sized cotton cloth, and consequently separates from the cloth when wet. It is much more useful when spread upon old or unglazed cotton, for it then penetrates the fibre and renders it partially water-proof. As all resinous plasters are somewhat irritating to fresh wounds, it may frequently be advantageous to employ the isinglass plaster of Liston, which, when properly prepared, is nearly identical with the best water-proof court-plaster.† It should be spread upon some fabric impervious to water, or it will be loosened by the slightest moisture.

There is often considerable difficulty in applying plasters neatly and firmly, owing to the elasticity of the soft parts causing the wound to gape. To obviate this inconvenience, Liston was in the habit of securing the flaps by means of a few sutures, removing them as soon as the plasters become fixed. I have often found it convenient to apply the strips of plaster in the following manner, suggested by the common uniting bandage. The strips are applied in pairs, one strip of each pair being made narrower than the other, so that it may pass easily through a button-hole cut transversely in the wide strip, at about the middle of its length. The wide and narrow strips are applied alternately to the sides of the stump, so that the holes in the wide strips fall a little above the cut edge of the integument; the free end of each narrow strip is then passed through the hole in the opposite wide one, and by drawing upon the two ends the lips of the wound are closely approximated. When everything is adjusted, the ends of the plasters are secured by sticking them down smoothly in the position they happen to assume. Used in this way the plasters offer many of the advantages generally ascribed to sutures, and they can besides be readily loosened and readjusted without disturbing other parts of the wound.‡

The next condition for the accomplishment of speedy union is the

\* I have been led to the discussion of this question by the experience of several cases occurring in the army, in which serious and sometimes fatal accidents appeared to depend upon the tension of flaps confined by strong thread or wire sutures. See, also, Larrey's Campaign in Saxony, in the last volume of the *Memoirs*.

† Liston's plaster, as finally improved by the inventor, "is composed of a solution of isinglass in spirit spread on slips of oiled silk; or silk glazed on one side only, and on the unglazed side." (*Liston's Practical Surgery*, ch. ii., on the Union and Dressing of Wounds.)

‡ Since adopting this plan in the army hospitals, I find that something very similar is described and strongly recommended by Prof. Nathan Smith. (*Op. cit.*, page 222.)

absence of inflammation,\* for the slightest inflammatory action is sufficient to prevent immediate union, and but a slight degree of it is consistent with union by primary adhesion. The dressings, therefore, for the first few days, should be such as are least likely to irritate the freshly divided tissues; all greasy applications should be avoided, and the parts should be disturbed as little as possible. The free use of water at this period generally does more harm than good, for it loosens the plasters and thus disturbs the apposition of the parts. Perhaps the best dressing is a narrow compress of soft linen, moistened with water and covered with oiled silk† to prevent evaporation; this will not need to be removed oftener than once or perhaps twice a day, and it is both neat and unirritating. After suppuration begins, the lateral compresses should be carefully adjusted at each dressing, so as to keep the granulating surfaces in contact with each other, and to prevent the accumulation of pus between them. At this stage, if the suppuration is abundant, no other dressing is required than lint or tow in sufficient quantity to absorb the matter discharged in the interval between two successive dressings;‡ should the discharges be scanty, however, it will be best to apply to the wound a narrow strip of linen greased with tallow or simple cerate. Saturating the dressings with water can be of no conceivable use during the progress of granulation; it is a slovenly practice, and generally causes much discomfort to the patient by wetting the bedding. The stump should be lightly covered, and protected from the weight of the bed-clothes. An excellent covering for the end of the stump may be made of a handkerchief, or a square piece of cotton or linen cloth, confined by a couple of turns of a roller; this will prevent the access of flies to the wound, and will thus afford an effectual protection against the development of maggots.§

The danger of accident from the pressure of the bone against the soft coverings depends, as has already been shown, upon the progressive retraction of the muscles, and it must be met, if at all, by combating this cause. This may be effected in two ways:—1st, by position, which, however, is more effectual in the leg than in the thigh; and 2d, by the application of a roller to the whole length of the stump.

The muscles of the thigh, whose tension is affected by changes in the position of the limb, are chiefly those upon the posterior and

\* See Paget's Lectures on Surgical Pathology, chap. ix., p. 133 of 2d Am. Edition.

† Instead of oiled silk we may use freshly oiled paper, rubber cloth, sheet rubber, tin foil, thin sheet lead from tea chests, or, on an emergency, a thick leaf, or a bit of soft bark, &c. &c.

‡ Some absorbent material is absolutely required in army practice, where there is no time for superfluous dressings. For this purpose there is probably nothing better or cheaper than tow or oakum; lint answers well, but old linen is of more value in the form of rags than when scraped or ravelled. Cotton batting does not absorb liquids readily.

§ The presence of maggots in a wound is a disgrace to the dresser; they cause great irritation and utterly prevent union by first intention, and although in some cases of sloughing wounds they may hasten the "cleaning" by expediting the fall of the sloughs, the same end may be much better attained by the use of stimulant and antiseptic lotions.

*On Amputation of the Thigh.*

inner aspect of the femur.\* The great mass of the muscles of this region, which arise from the tuberosity of the ischium, are put in a state of tension when the end of the stump is elevated, but are relaxed when the thigh is extended nearly in a line with the body. Three of the four anterior muscles, on the other hand, arise from the femur, and are therefore unaffected by the change in position. A change, therefore, from the elevated position which the stump is apt to assume, to the horizontal, may suffice, of itself, to relieve a slight degree of tension of the coverings, and is, besides, a valuable adjuvant to the method next to be described.†

The use of the roller to prevent muscular retraction depends upon the principle that when a muscle contracts in length it increases proportionally in diameter; if, therefore, this increase in diameter be prevented, the muscular contraction cannot take place; and this is as true of a limb as of a single muscle. The remedy, then, for the tension which depends upon the retraction of the muscles, consists simply in applying a roller firmly and evenly to the whole stump as far as the next articulation, thus compressing all the muscles and effectually preventing their contractions. The roller should not be changed until it becomes soiled or loosened, and it is well to apply it in two parts, letting the main roller extend to within two or three inches of the end of the stump, and finishing the operation with a second shorter piece which may be changed at each dressing. The use of the roller in the manner and for the purpose just described, although taught by almost every surgeon of note who has written on the subject of amputations,‡ has, nevertheless, fallen of late into comparative neglect. A few surgeons,§ who have adopted flap methods with flaps of very great length, have been able safely to dispense with the roller in a great majority of cases, but even after the best operation the flaps may slough, or unexpected retraction may take place, so as, after all, to render some artificial support necessary. In the common circular operation, as performed by Gooch, Alanson, Benj. Bell, Hey, and John and Charles Bell, the roller always formed an essential feature in the after-treatment, although these surgeons all inculcate the necessity of sawing the bone as high as it can be denuded, by the use of the retractor, after dividing the muscular and tendinous attachments at the *linea aspera*. I am not prepared, however, even in the case of circular operations, to deny the possibility, under favorable circumstances,

\* The long head of the biceps, the semi-membranosus, semi-tendinosus and adductor magnus.

† In the middle and upper thirds of the leg, where the muscles of the calf preponderate enormously over all the others, a bent position of the knee affords very great relief by relieving the tension of the coverings and preventing perforation of the skin by the sharp spine of the tibia. So great is the advantage derived from this position, that I always adopt it, turning the patient upon his side, whenever there appears to be the slightest tension of the integuments in front.

‡ Gooch. Alanson. Lonis. Benj. Bell. Richerand. Astley Cooper. Hennen. John and Charles Bell. Guthrie. Sedillot and others.

§ Liston. Teale.



of sawing the bone high enough to enable the dresser safely to dispense with the roller, but I am confident that, to ensure this safety, the bone must be sawn so much higher than is the usual practice as to render the circular methods, in many cases, extremely difficult of performance. With the exception of a very few double-flap operations, I have scarcely ever seen a stump of the thigh in which the use of the roller was not indicated during the greater part of the after-treatment; and whenever it has been tried, I have never known it fail to produce very decided benefit.\* In applying the roller, certain precautions are necessary—it should be applied from above downwards, beginning in the vicinity of the articulation next above the point of amputation, and it should extend nearly or quite to the extremity of the stump, in order that it may compress the muscles of the limb throughout their entire length. Thus in the thigh, a few turns should be first taken around the pelvis, and the thigh approached in the manner known as the “spica.” If the soft parts are deficient, or if they show a tendency to retract to an unusual degree, the bandage must be very firmly but smoothly applied, and for this purpose the roller with two heads is to be preferred. There is

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\* A late writer (Symonds, *Med. Times and Gazette*, Sept. 8, 1860, p. 230) has doubted the efficacy of the roller in preventing muscular retraction after amputation. It may be well, therefore, briefly to state my own experience. 1st. I have seen a few excellent stumps of the thigh in which the roller had not been used during any part of the treatment, but in all these cases the coverings were left very long, and extensive union took place by first intention. This was especially true of amputations performed with two equal flaps, which accords with the results given by Mr. Teale, in whose operation, also, the flaps are of very ample length. 2d. I have seen a large number of cases in which union by first intention has either failed or has been confined to the integuments, and in which retraction of the soft parts has taken place to such an extent as either to tear open the newly-formed adhesions or to threaten perforation of the coverings by the pressure of the end of the bone against them. In all cases of this character, I have immediately applied the roller in the manner described, and in every instance with the happiest result. In this way I have generally succeeded in covering the bone, even in cases in which the soft parts have been very deficient, and in all cases in which the bone has not already found its way through the coverings, I have been able to relieve the tension and prevent the occurrence of this accident. In other cases, where the stump has been very painful from the same cause, although there was probably no great danger of perforation, I have at once relieved the pain and completely arrested the spasmodic twitching of the muscles, which was often present as the result of the irritation. 3d. In amputations of the leg near the ankle, the roller is of but little use, for the integuments are firmly tied to the bones by the inter-muscular and inter-tendinous fasciæ, and the retraction of the great muscles of the calf only tends to draw the tendo Achillis a little higher in its sheath. The same is undoubtedly true of amputation at or near the wrist, of the toes, fingers, &c., but in the fleshy part of the leg, and often in the fore-arm, the roller may be made to render good service. In the middle and upper part of the leg the relaxation of the soft parts may be greatly assisted by flexing the leg upon the thigh, allowing the patient to lie on his side, as was practised, for the same reason, by Mr. Pott, in fractures of the leg and thigh, and I have in this way several times prevented the perforation of the integument by the sharp angle of the tibia.

Since I have had this paper in preparation, I have requested my friend and former pupil, Dr. A. M. Wilder, Surg. U. S. Vols., to report to me such cases of amputation as might fall under his observation. I am indebted to him for notes of fourteen cases, of which nine were of the thigh, two of the arm, and three of the leg. Of the nine amputations of the thigh, one was treated with the roller from the beginning; no protrusion of the bone took place, but the patient died from exhaustion a fortnight after the operation. Of eight cases treated without the roller, the bone protruded in six, and in the other two the coverings were tense and painful where they pressed upon the end of the bone. Five of the eight stumps were then dressed with the roller, with immediate relief to the bad symptoms; the three stumps not rolled became conical. Of two stumps of the arm, one, treated without the roller, became conical; the other, which was very painful and threatened perforation, was completely relieved by the roller. The three cases in the leg were all treated by the roller, and the muscles of the calf were also relaxed by keeping the knee bent at nearly a right angle to the thigh; they all did well.



scarcely any danger of rolling a stump too tightly, if only the pressure is equally distributed, and although great trouble may be caused by the unskilful use of the roller after amputations, it is not to be compared to the danger which would attend the same lack of skill in bandaging a fractured limb.\* A second use of the roller is to prevent the burrowing of pus among the muscles and other tissues of the stump. This accident is of pretty frequent occurrence after amputation of the thigh, owing in part to the elevated position which the stump generally assumes during the progress of the case, and still more to ill-advised attempts to secure early union by the use of sutures. In such cases the careful use of the roller is of the greatest benefit.

The soft parts may also be relaxed in some cases, by means of two or more strips of adhesive plaster applied to the sides of the stump and connected with a weight hung over the foot of the bedstead. In this method,† however, a roller should be applied to prevent the slipping of the plasters, and the result is no better than that which follows the use of the roller alone.

A kind of paraphymosis or strangulation of the end of the stump by the skin is described by several writers. It can only occur when the skin and muscles have been divided nearly at the same level, but in such a case it may give rise to serious complications. It is rarely possible to make a good stump under such circumstances, but much benefit may result from the application of a roller, so as to relax the superficial muscles and permit the skin to be drawn down beyond the other soft parts. If the strangulation has existed for some time it may be necessary to divide the skin longitudinally for an inch or two on each side of the limb, especially if it has already become adherent to the subjacent muscles.

Great retraction of the integuments, accompanied by more or less protrusion of the bone, is often observed in stumps which have been badly managed. This may often be much relieved by the application of the roller, although the stump will be always defective from the want of soft parts to protect the end of the bone. In one or two cases of this kind, I have succeeded in materially improving the result by removing the prominent apex of the cone, which projected through the coverings, and sawing off the bone at the same level. By this comparatively trivial operation nothing was removed, except about an inch of the bone and a ring of thickened and partially ossified periosteum (callus). No further retraction took

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\* This is perhaps the place to mention a common and very bad use which is often made of the roller, and which is taught in many of the handbooks on minor surgery. I allude to the "capelline" or recurrent bandage, in which the roller is so managed as to cover the end of the stump like a cap. The capelline was originally employed for the purpose of moulding the end of the stump into a symmetrical form, but this slight advantage is more than neutralized by its tendency to push up the soft parts and thus denude the bone. See *Thil-lage, Traité des Bandages, &c.*, 2me Ed., Paris, 1809, p. 269.

† Attributed by Malgaigne to Follioy, of Brest. See *Manuel de Médecine Opératoire*, chap. xi., on Amputations.

place, and the skin was readily drawn together over the whole end of the stump by means of strips of plaster, used in the manner already described (page 29). The stump was quite handsomely rounded, and its only defect was that the bone was not so well protected by projecting muscle as it would have been had the bone been cut shorter at the time of the amputation and the stump been more judiciously treated.